

MANGROVE SOILS OF THE BEACHWOOD AREA, DURBAN

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ABSTRACT

Soil samples from almost pure *Avicennia marina* (Forsk.) Vierh. and *Bruguiera gymnorhiza* (L.) Lam. stands were characterized for their physical and chemical properties. All soils examined were weakly acidic, high in clay, organic matter, and moisture at saturation. Acidity increased with air drying. The soils were characterized by low bulk densities, moderate exchange acidities and high CEC. The predominant cations were sodium and magnesium. The ratio of sodium and magnesium to exchangeable bases was very high. The soils were low in available phosphorus and soluble sulphate. Generally, *Avicennia* soils were higher in pH, organic matter, CEC, exchangeable bases and lower in clay, exchange acidity and aluminium than *Bruguiera* soils.

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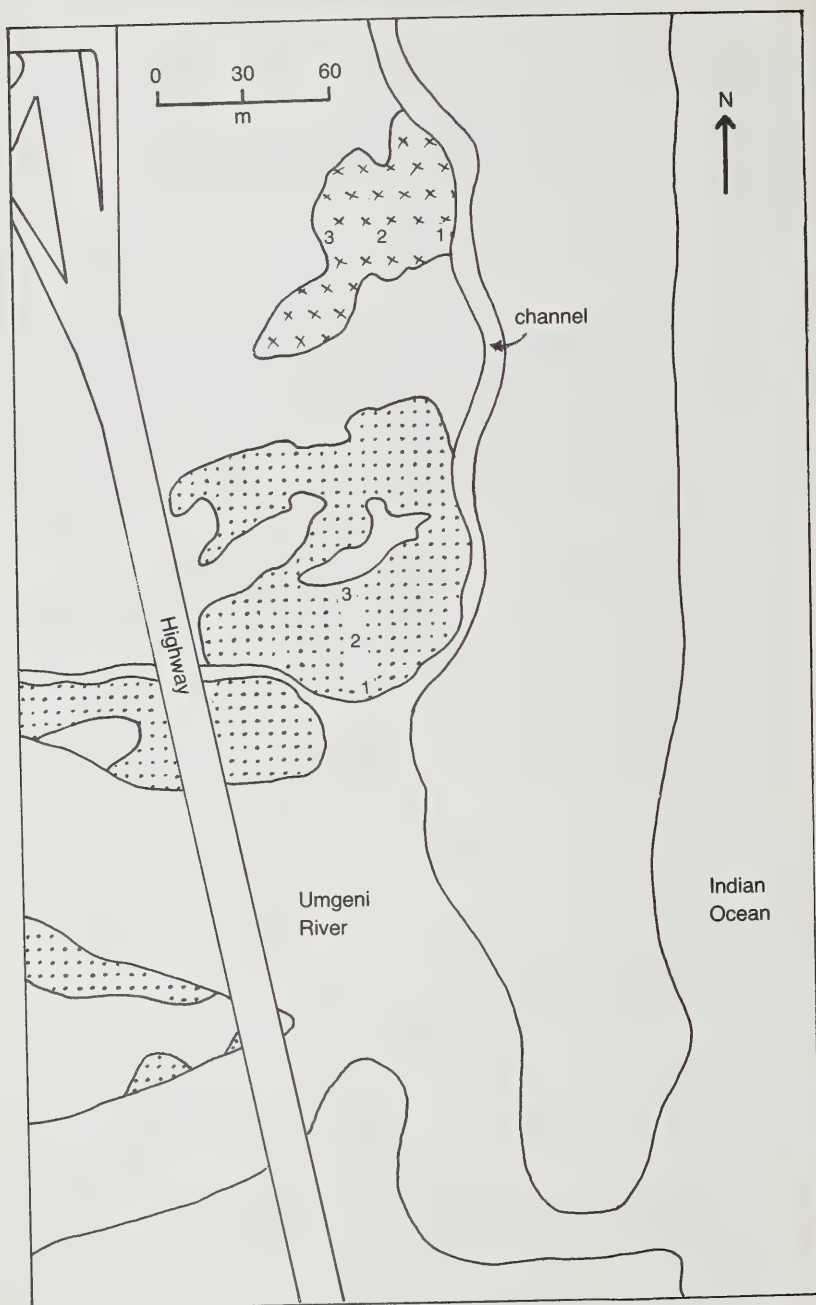
WORTELBOOMGRONDE IN DIE BEACHWOODGEBIED, DURBAN

Die fisiese en chemiese eienskappe is bepaal van grondmonsters van twee standplase waarop feitlik uitsluitlik *Avicennia marina* (Forsk.) Vierh. en *Bruguiera gymnorhiza* (L.) Lam. voorkom. Die gronde wat ondersoek is, het swak suurgehalte, 'n hoë klei en organiese materiaal inhoud en 'n hoë voginhoud by versadiging gehad. Die suurgehalte het tydens uitdroging verhoog. Die gronde is gekenmerk deur lae massa digtheid, matige uitruil-suurgehaltes en 'n hoë kation uitruilkapasiteit. Die dominante katione was natrium en magnesium. Die verhouding van natrium en magnesium tot uitruilbare base was baie hoog. Die beskikbare fosfor en oplosbare sulfaat was laag. In die algemeen was die *Avicennia* gronde hoër in pH, organiese materiaal, kation uitruilvermoë, uitruilbare base en laer in kleigehalte, uitruilsuurgehalte en aluminium as die *Bruguiera* gronde.

INTRODUCTION

Mangrove vegetation occurs along many of the estuaries on the east coast of South Africa extending as far south as East London, S 33 ° (Macnae, 1962). In these estuaries mangroves occur up to the extreme tidal limit at high spring tides. The distribution of mangroves in intertidal zones is influenced by factors such as salinity, drainage, soil, water currents and climate. Several of these factors were reviewed recently (Chapman, 1976).

Mangrove species show a characteristic zonation within the swamp (Chapman, 1940; Hind, 1954; Bourdeau & Adams, 1956; Thom *et al.*, 1975). In the Beachwood marsh area the primary mangrove species is *Avicennia marina* which occupies the seaward portion of the swamp. The only other important mangrove species is *Bruguiera gymnorhiza* which usually occurs on the landward side of the *Avicennia* zone.



Distinct zonation patterns in mangrove communities locally have been attributed to various factors with little or no experimental verification. The ecology of mangrove communities has been studied in greater detail in other countries. Many of these studies were reviewed by Chapman (1976).

In this paper mangrove soils have been characterized to determine their possible role in influencing the establishment of distinct zones of mangrove species and to indicate the effect of mangrove species upon the soil. In addition, the nature of mangrove soils in South Africa has received little or no attention from research workers. It is hoped that this study will provide information which will be useful not only in understanding the ecology of our local mangrove communities but also in the conservation and management of our rapidly depleting mangrove areas.

THE STUDY AREA

The Beachwood area is located at the Umgeni River estuary, which is about 6 km to the north of Durban Bay. The mangrove area, situated on coastal sand dunes, is about 120 000 m² in extent. The area is drained by a channel which runs from a freshwater source in the north to the Umgeni estuary in the south (Fig. 1). The marsh is usually subject to tidal inundation twice daily. The mean tidal range is about 1.5 metres.

The climate in this area is warm temperate according to Köppen's classification. The mean annual temperature is 20.5 °C and the mean annual rainfall is 1 008 mm. The slope throughout the marsh is less than one degree.

METHODS

Soil samples were collected from almost pure stands of *A. marina* and *B. gymnorhiza*. In each mangrove area samples were collected from three sites along a transect 15, 30 and 45 metres from the edge of the channel (Fig. 1). All samples were air dried, ground with a pestle and mortar, passed through a 2 mm sieve and stored in glass bottles.

The following analytical procedures were used: particle size distribution by the hydrometer method (Bouyoucos, 1962); pH of field-moist and air-dried samples on 1:1 soil to water suspension using a glass electrode (Jackson, 1958); moisture at saturation (Bower & Wilcox, 1965); exchange acidity by extraction with barium acetate and titration with NaOH; aluminium by the aluminon method (Yuan & Fiskell, 1959); acetate soluble sulphate (Bardsley & Lancaster, 1965); organic matter by the Walkley-Black method (Jackson, 1958) and available

FIG. 1.

Map of part of the Beachwood mangrove area showing the distribution of mangroves ([] predominantly *Avicennia*, [x x x x x] predominantly *Bruguiera*) and the sampling areas (1, 2, 3).

phosphorus extracted with sulphuric acid containing ammonium sulphate and determined by the chlorostannous-reduced molybdophosphoric blue colour method (Jackson, 1958). Exchangeable cations were extracted with 1N ammonium acetate at pH 7. Concentrations of K, Mg and Ca in the extracts were determined by atomic absorption. Sodium was determined by flame emission spectrometry. Bulk density was measured using a steel cylinder with a volume of 772 cm³. The cation exchange capacity was obtained by summation of the exchangeable bases and exchange acidity.

RESULTS AND DISCUSSION

Particle size distribution and bulk density

The particle size distribution of mangrove soils (Tables 1 and 2) was similar throughout all profiles. There was an increase in sand content in the seaward edge of the *Avicennia* zone (profile 1).

All other profiles had a heavy texture. Most horizons were classified as clays. Lower down the profile the sand content increased suggesting the approach to the underlying sand dunes. The high sand content of profile 1 in the *Avicennia* zone could be attributed to the turbulent and churning action of the tidal waters which only permitted the coarse soil fraction to settle out of suspension. Part of the sand

TABLE 1.
Particle size distribution of *Avicennia* soils.

Layer	Depth mm	Particle size distribution %				Textural class
		Coarse sand	Fine sand	Silt	Clay	
1	0-200	86	Profile 1		4	sand
2	200-400	34	20	14	32	sandy clay loam
3	400-600	32	22	16	30	sandy clay loam
4	600-800	32	34	12	22	sandy clay loam
5	800-1 000	34	22	18	26	sandy clay loam
1	0-200	19	Profile 2		3	clay
2	200-400	28	2	24	46	clay
3	400-600	19	23	20	38	clay loam
4	600-800	15	35	18	32	sandy clay loam
5	800-1 000	11	27	22	40	clay
1	0-200	13	Profile 3		10	clay
2	200-400	7	10	24	59	clay
3	400-600	5	24	20	51	clay
4	600-800	3	20	30	47	clay
5	800-1 000	14	45	2	39	sandy clay

TABLE 2.
Particles size distribution of *Bruguiera* soils.

Layer	Depth mm	Particle size distribution %				Textural class
		Coarse sand	Fine sand	Silt	Clay	
			Profile 1			
1	0-200	5	13	38	56	clay
2	200-400	4	16	26	54	clay
3	400-600	14	6	22	58	clay
4	600-800	3	19	20	58	clay
5	800-1 000	36	28	14	22	sandy clay loam
			Profile 2			
1	0-200	3	15	26	56	clay
2	200-400	11	9	26	54	clay
3	400-600	4	38	22	36	clay loam
4	600-800	13	25	22	40	clay
5	800-1 000	4	18	18	60	clay
			Profile 3			
1	0-200	16	1	26	57	clay
2	200-400	4	9	22	65	clay
3	400-600	7	6	24	63	clay
4	600-800	10	39	16	35	sandy clay
5	800-1 000	19	44	10	27	sandy clay loam

probably originated from wind-blown material from adjacent sand dunes. *Avicennia* is the pioneer species at Beachwood and is able to colonise sandy substrates. Colonisation results in consolidation and stabilization of the substrate. This in turn permits the accretion of finer particulate matter such as silt and clay. Once the nature of the substrate is altered sufficiently, not only by *Avicennia* colonisation, but also by other soil forming processes, *Bruguiera* becomes established. The particle size distribution suggests that greater deposition of finer sediments is occurring further away from the water's edge. The high proportion of fine soil fractions in the surface layers of the *Bruguiera* zone (Table 2) is probably due to the slow rate of inundation of the swamp and to the low slope which allows water to remain in the swamp for prolonged periods. Most of the silt and clay that is deposited in the swamp originates from the coastal rivers and the off-shore sea.

The bulk density values were low and ranged from 1.41 g cm⁻³ to 0.61 g cm⁻³ (Tables 3 and 4).

The high bulk density in the surface layer of profile 1 of the *Avicennia* zone was due to the sandy nature of the soil. The low bulk densities in the remaining profiles are a reflection of the high clay and organic matter contents. The high clay content indicates that the soils have a high water-holding capacity and poor

TABLE 3.
Bulk density pH and moisture at saturation of *Avicennia* soils.

Layer	Depth mm	Bulk density g cm ⁻³	pH (H ₂ O)		Moisture at saturation %
			Field moist	Air dry	
Profile 1					
1	0–200	1,41	6,3	6,1	32,7
2	200–400	0,87	6,4	5,9	37,6
3	400–600	0,97	6,2	5,7	35,3
4	600–800	1,08	6,0	5,8	25,8
5	800–1 000	0,95	6,1	5,8	28,7
Profile 2					
1	0–200	0,88	5,6	5,3	40,5
2	200–400	0,73	5,7	5,5	40,6
3	400–600	0,73	5,7	5,3	34,2
4	600–800	0,91	5,8	5,5	33,5
5	800–1 000	0,79	5,8	5,7	37,2
Profile 3					
1	0–200	0,75	5,9	5,2	42,5
2	200–400	0,67	5,9	5,3	42,4
3	400–600	0,97	5,8	5,3	36,9
4	600–800	0,61	5,8	5,3	38,9
5	800–1 000	0,84	5,8	5,4	35,4

TABLE 4.
Bulk density, pH and moisture at saturation of *Bruguiera* soils.

Layer	Depth mm	Bulk density g cm ⁻³	pH (H ₂ O)		Moisture at saturation %
			Field moist	Air dry	
Profile 1					
1	0–200	1,01	5,9	5,5	39,2
2	200–400	0,95	5,8	5,2	39,4
3	400–600	0,85	5,8	5,5	38,3
4	600–800	0,82	5,9	5,5	37,2
5	800–1 000	0,93	6,0	5,4	32,1
Profile 2					
1	0–200	1,01	5,6	5,2	38,0
2	200–400	0,95	5,6	5,4	38,3
3	400–600	0,86	5,7	5,2	29,7
4	600–800	0,88	5,8	5,3	34,5
5	800–1 000	0,84	5,9	5,3	37,6
Profile 3					
1	0–200	0,95	5,7	5,2	37,2
2	200–400	0,84	5,8	5,4	37,2
3	400–600	0,88	5,8	5,5	37,6
4	600–800	1,05	6,0	5,5	33,4
5	800–1 000	0,98	5,4	5,4	29,5

drainage. The moisture content at saturation was high for both mangrove zones (Tables 3 and 4). These physical properties, together with the intermittent salinity, suggest that the soils have a low agricultural potential.

Acid properties

Soils from all profiles were moderately acid (Tables 3 and 4). Field moist pH values in the *Avicennia* zone ranged from 5,6 to 6,4 while in the *Bruguiera* zone the range was from 5,6 to 6,1. Generally, soils in the *Bruguiera* zone were slightly more acidic than in the *Avicennia* zone. In all horizons the pH values decreased with air drying. Air dry pH values ranged from 5,2 to 6,1 in the *Avicennia* zone and from 5,2 to 5,5 in the *Bruguiera* zone. This study confirms previous reports that drainage and reclamation of mangrove areas produce acid soils (Fleming & Alexander, 1961; Pons & Pons, 1974; Coultas & Calhoun, 1976; Van Breen, 1976).

The exchange acidity of *Avicennia* soils was lower than that of *Bruguiera* soils (Tables 5 and 6).

In *Avicennia* soils the exchange acidity ranged from 3 to 5,7 me/100 g while in *Bruguiera* soils the range was from 5 to 7,4 me/100 g. In all soil profiles the exchange acidity generally increased with depth. The aluminium content of *Avicennia* soils ranged from 0,08 me/100 g to 0,28 me/100 g (Table 5). In

TABLE 5.
Acid properties of *Avicennia* soils.

Layer	Depth mm	Exchange acidity me/100 g	Al ³⁺ me/100 g	Soluble SO ₄ ²⁻ me/100 g
Profile 1				
1	0-200	4,3	0,15	0,04
2	200-400	3,0	0,19	0,15
3	400-600	4,0	0,21	0,16
4	600-800	5,0	0,23	0,24
5	800-1 000	5,7	0,28	0,25
Profile 2				
1	0-200	4,0	0,08	0,12
2	200-400	3,6	0,20	0,26
3	400-600	4,7	0,21	0,19
4	600-800	5,1	0,24	0,14
5	800-1 000	5,4	0,27	0,16
Profile 3				
1	0-200	4,2	0,15	0,17
2	200-400	3,9	0,19	0,17
3	400-600	4,9	0,20	0,30
4	600-800	5,0	0,21	0,23
5	800-1 000	5,4	0,28	0,27

TABLE 6.
Acid properties of *Bruguiera* soils.

Layer	Depth mm	Exchange acidity me/100 g	Al ³⁺ me/100 g	Soluble SO ₄ ²⁻ me/100 g
Profile 1				
1	0-200	5,0	0,23	0,10
2	200-400	5,6	0,26	0,11
3	400-600	5,8	0,30	0,17
4	600-800	6,4	0,29	0,18
5	800-1 000	7,4	0,31	0,17
Profile 2				
1	0-200	5,0	0,24	0,11
2	200-400	6,2	0,24	0,14
3	400-600	6,7	0,26	0,25
4	600-800	6,9	0,27	0,18
5	800-1 000	7,2	0,28	0,24
Profile 3				
1	0-200	5,1	0,17	0,12
2	200-400	5,5	0,21	0,16
3	400-600	6,0	0,25	0,12
4	600-800	6,7	0,28	0,16
5	800-1 000	7,1	0,31	0,12

Bruguiera soils the aluminium content was higher, the range being from 0,21 me/100 g to 0,31 me/100 g (Table 6). Soluble sulphate levels were variable in both mangrove zones (Tables 5 and 6). Generally subsoils contained higher levels of sulphate than the surface layers. Aluminium, sulphate and hydrogen ions were probably the main contributors to the exchange acidity.

Organic matter

Surface layers of all profiles were high in organic matter (Tables 7 and 8).

Generally the organic matter content decreased with depth within each profile. In the *Avicennia* zone the organic matter content increased with distance landwards. This was due to the greater density of *Avicennia* inland. The dense pneumatophores in the *Avicennia* zone probably trapped leaves and other debris thereby contributing to high organic matter. *Avicennia* soils had higher organic matter contents than *Bruguiera* soils. *Bruguiera*, unlike *Avicennia*, does not produce pneumatophores which are able to trap debris during tidal inundation. The darker soil colour observed with distance landwards is probably a reflection of the high organic matter content. High soil organic matter in intertidal swamps is usually associated with a slow rate of silting (Moorman & Pons, 1974).

TABLE 7.

Organic matter, cation exchange capacity, exchangeable cations and available phosphorus of *Avicennia* soils.

Layer	Depth mm	Organic matter %	CEC me/100 g		Exchangeable cations (me/100 g)				Available P ugml ⁻¹
					Ca	Mg	K	Na	
Profile 1									
1	0–200	4,6	23,7	3,3	3,4	1,0	11,7	0,30	
2	200–400	3,6	54,3	4,2	18,5	1,6	27,0	0,63	
3	400–600	2,8	44,6	3,9	16,4	1,2	19,1	1,20	
4	600–800	2,5	42,6	5,1	9,4	1,4	21,7	1,13	
5	800–1 000	3,2	50,7	6,0	15,2	1,6	22,2	0,33	
Profile 2									
1	0–200	5,4	56,0	3,0	21,3	2,0	25,7	0,55	
2	200–400	4,8	65,6	4,5	23,4	2,3	31,8	0,55	
3	400–600	3,9	60,2	3,6	24,6	2,5	24,8	0,50	
4	600–800	3,9	57,2	3,4	17,6	2,0	29,1	0,25	
5	800–1 000	3,9	57,5	4,5	19,7	1,8	26,1	0,55	
Profile 3									
1	0–200	6,3	72,8	4,3	25,0	2,3	37,0	0,65	
2	200–400	5,4	83,3	5,1	25,8	3,3	45,2	0,45	
3	400–600	4,8	75,8	5,6	25,8	2,5	37,0	0,38	
4	600–800	4,9	77,4	4,7	25,8	2,8	39,1	0,53	
5	800–1 000	4,1	69,0	5,0	21,3	2,5	34,8	0,13	

TABLE 8.

Organic matter, cation exchange capacity, exchangeable cations and available phosphorus of *Bruguiera* soils.

Layer	Depth cm	Organic matter (%)	CEC me/100 g	Exchangeable cations (me/100 g)				Available P ugml ⁻¹
				Ca	Mg	K	Na	
Profile 1								
1	0-200	4,2	47,6	3,2	17,4	2,0	20,0	0,25
2	200-400	3,7	49,6	2,0	16,8	2,1	23,1	0,28
3	400-600	4,4	60,4	3,8	17,2	3,6	30,0	0,60
4	600-800	4,8	51,3	3,5	14,4	2,2	24,8	0,68
5	800-1 000	2,4	46,7	1,4	18,9	1,2	17,8	0,65
Profile 2								
1	0-200	3,8	49,5	2,6	17,2	1,6	23,1	0,53
2	200-400	3,6	50,8	2,4	16,8	1,5	23,9	0,73
3	400-600	3,6	41,0	1,4	12,3	0,6	20,0	0,78
4	600-800	3,4	53,4	2,4	15,6	1,5	27,0	0,65
5	800-1 000	3,5	67,6	3,5	17,4	2,5	37,0	0,50
Profile 3								
1	0-200	4,7	48,9	3,4	17,2	1,5	21,7	0,35
2	200-400	4,5	58,0	2,8	15,6	2,3	31,8	0,25
3	400-600	4,0	55,4	2,4	17,2	2,0	27,8	0,20
4	600-800	3,4	54,7	1,7	16,8	1,7	27,8	0,48
5	800-1 000	2,5	58,6	1,6	14,4	1,6	33,9	0,18

CEC, exchangeable cations and phosphorus

All soil profiles had high cation exchange capacities (CEC). In *Avicennia* soils the CEC ranged from 23,7 to 83,3 me/100 g (Table 7). The CEC generally increased with distance landwards in the *Avicennia* zone. This was probably a reflection of the trends in organic matter and clay contents. Generally *Bruguiera* soils had lower CEC than *Avicennia* soils, the range being from 41 to 67,6 me/100 g (Table 8). The high CEC of both mangrove soils suggests that these soils have a potentially high sink for cations. All soils contained large amounts of exchangeable sodium and magnesium (Tables 7 and 8). The ratio of exchangeable sodium and magnesium to extractable bases was very high probably because of the high concentration of sodium and magnesium in sea water. Soils inundated by tides equilibrate to have higher concentrations of exchangeable sodium and magnesium than upland soils (Coover *et al.*, 1975). The moderately acidic nature of the soils suggests that much of the calcium and magnesium is present in the form of sulphates. Generally, *Bruguiera* soils were lower in sodium, magnesium, calcium and potassium than *Avicennia* soils (Tables 7 and 8). This is primarily due to the proximity of *Avicennia* soils to the sea. *Avicennia* soils are more frequently inundated by saline water than *Bruguiera* soils. With distance landwards there is also greater dilution from freshwater sources.

In both mangrove soils, available phosphorus levels were low, the levels being higher in *Bruguiera* soils. At the acid pH values reported for these soils phosphorus was probably fixed by iron and aluminium. Air drying of the moist soil decreased the pH and increased phosphorus fixation. Low phosphorus levels in mangrove soils were reported by Huynh-cong-Tho & Egashira (1976).

General

In both mangrove zones great difficulty was experienced in obtaining deep sub-surface samples with the soil corer. The high water table limited the sampling depth to 1 m. Both mangrove soils showed very little profile differentiation up to this depth.

Unfortunately, pedological descriptions of the soil profiles were not undertaken for two reasons: firstly, as a result of the high water table holes dug in the marsh were completely filled with water within a few minutes; secondly the Beachwood area is a proclaimed nature reserve so that disturbance in collection of soil samples was kept to a minimum.

The data obtained for Beachwood soils differ markedly from those reported for a mangrove swamp in the Sydney district, Australia, by Clark & Hannon (1967). The soils in Sydney were predominantly sandy, surface and sub-surface samples comprising more than 75 % coarse sand. Clay content was less than 5 %. In the present study the clay content was as high as 59 % in the *Avicennia* zone and 65 % in the *Bruguiera* zone. Moorman & Pons (1974) and Pons & Pons (1974) reported

that mangrove soils in South America were predominantly clayey in texture and that very little coarse material was deposited in the mangrove proper. In West Malaysia the mangrove sediments were also found to be clayey (Diemont & van Wijngaarden, 1974). The coastal areas around Sydney are probably backed by sandy formations which could explain the high sand content. Clark & Hannon obtained high pH values (5.5 to 7.3) probably because of the presence of calciferous shell particles in the sand and extremely low CEC (0.38 to 0.84 me/100 g). Exchangeable bases were not determined by the Australian workers apparently because of the low CEC.

This study has revealed important differences between *Avicennia* and *Bruguiera* soils, although these differences were not subject to statistical analyses. Generally, *Avicennia* soils were higher in pH, organic matter, CEC, exchangeable bases and lower in clay, exchange acidity and aluminium than *Bruguiera* soils.

The composition of mangrove sediments probably differs in different areas and is determined to a large extent by various geogenetic parameters. These include factors such as climate, mineralogy of adjacent coastal areas and frequency of tidal inundation.

Although differences do exist between soils in the *Avicennia* and *Bruguiera* zones it is doubtful if these differences alone determine distinct zones of mangrove species. Differences in soil properties must be considered in relation to the habitat variables such as physiography, climate, salinity, soil drainage, water currents and salt spray. This conclusion is supported by the findings of Diemont & van Wijngaarden (1974) that there is a good relationship between vegetation and frequency of flooding, physiography and soil properties in the tidal areas of West Malaysia.

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